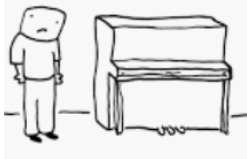# Transferring Piano Performance Control Across Environments

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I will reduce pedaling for the hall with good reverberation!

How do I control my fingers as if the pianist is in my room?

Motivation:
- **Physical Measurements:** Sound effect varies across environments (including room effects and piano devices).
- **Psychoacoustic studies:** Pianists adjust their performance control (Force, duration and pedaling) in different environments.
- **MIDI Representations** of performance controls enables replications of music through Player Pianos.

Aim:
- Given Environment **A** and a piano performance under **A**, Find an optimal control in Environment **B** so that performance **B** sounds like **A**.

Contributions:
- First method to transfer controls on player pianos to cope with deviation of environments.
- Provide measurements of performance under different environments and conduct listening test upon them.

Measurement of Performance:
- Measured velocity-intensity effect and note duration-audible duration effect.
- Environments has effect on both curves.
- The two factors has interaction effect to each other.
- The pedals of two pianos mostly varies on the effective ranges.
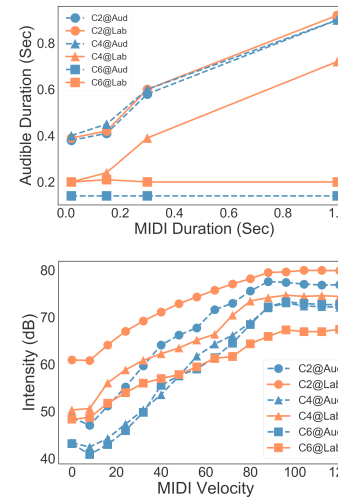
Fact:
- The tone of a fixed piano is only related to (a) the pitch being played, (b) the endmost velocity of the key, (c) the duration of the note, and (d) the use of sustain pedal.

Transfer Method (PETA):
- Defined environmental effect functions

$$E_i(v_i, d_i) = \left(f_i(v_i, d_i), g_i(v_i, d_i) \right)$$
$$= (I_i, D_i), \text{ for } i = 1, 2.$$

- The optimal transferred control is a minimizer as

$$(v_2^*, d_2^*) = \arg\min_{v,d} \left\| E_2(v,d) - (I,D) \right\|$$
$$= \arg\min_{v,d} \left\| \left(f_2(v,d) - I, g_2(v,d) - D \right) \right\|.$$

- Conduct the iterative coordinate-search algorithm until convergence.

```
1: I ← f₁(v₁, d₁), D ← g₁(v₁, d₁)
2: v₂⁽⁰⁾ ← v₁
3: d₂⁽⁰⁾ ← d₁
4: do:
5:    v₂⁽ᵏ⁺¹⁾ ← arg minᵥ |f₂(v, d₂⁽ᵏ⁾) − I|
6:    d₂⁽ᵏ⁺¹⁾ ← arg min_d |g₂(v₂⁽ᵏ⁺¹⁾, d) − D|
7: while v₂⁽ᵏ⁺¹⁾ − v₂⁽ᵏ⁾ > δᵥ and d₂⁽ᵏ⁺¹⁾ − d₂⁽ᵏ⁾ > δ_d
8: (v₂*, d₂*) ← (v₂⁽ᵏ⁺¹⁾, d₂⁽ᵏ⁺¹⁾)
```

Representing Performance Controls

| Name	Pitch	Velcocity	Onset	Duration	Sustain Pedal
Notation	p	v	o	d	S
Value	0, 1, …, 88	0, 1, …, 127	Sec	Sec	0, 1, …, 127
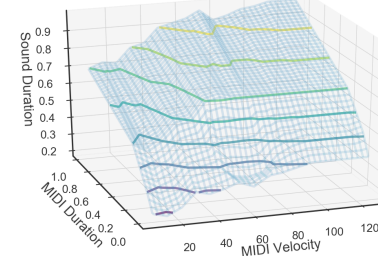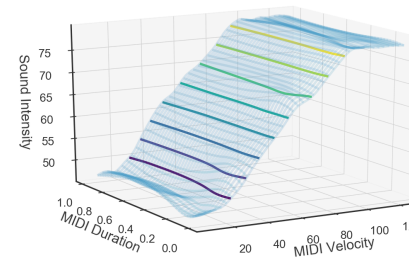
Experiments:
- Implemented PETA on Mozart's sonata, Debussy's etudes and Chopin's etudes.
- Conducted a listening test with 20 music players.

Original Control

Transferred Control
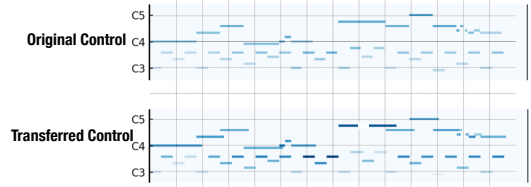
Results:
- Transferring velocity and duration has significant listening effect.
- Listeners could not quite tell the difference between the effect of a sustain pedal and a hold-on note.

DEBUSSY '**' : p<0.05   CHOPIN '*' : p<0.1   MOZART '' : p>0.1

W/O Transfer / W/ PETA1 / W/ PETA2
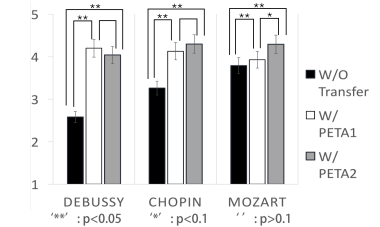
Future Works:
- We are currently moving on to explore the pedal transfer methods.
- Online learning can be applied to this algorithm and embedded in MIDI softwares connected to player pianos.

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